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TORSIONAL PROPERTIES OF TITANIUM A-110 AT HIGH RATES OF STRAIN

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Introduction

An experimental study was made to determine the effects of strain rate, temperature, type of notch, and size of specimen on titanium A-110 tested in torsion. Notched cylindrical specimens having root diameters of 3/16 inch and 3/8 inch were used. The contour of the notches was circular at the root of the notch and the ratio of the notch radius to the root diameter, $\frac{r}{D}$, was 0.160. Three rates of torsional strain were obtained by using angular velocities of 0.5 rpm., 27 rpm., and 1300 rpm. for the flywheel which loaded the specimen. The tests were conducted at -100 F, room temperature, and 700 F.

The details of the method of testing and methods of determining the torsional properties are given in the final report (1)* on Contract N6Ori-071 (49) submitted in April 1955.

Experimental Results

The final results are plotted in Figs. 1 to 5. Each plotted point represents in general the average of three tests. Torsional properties determined from each test are given in Table I.

In Fig. 1 it is seen that the modulus of rupture is relatively insensitive to rate of strain for the three temperatures used in the tests. The modulus of rupture at 700 F. decreases about 40 per cent from that at room temperature. There is a slight increase in modulus of rupture at -100 F. from that at room temperature. These results are about the same as those reported (2) for unnotched specimens of titanium RC70 and RC130B.

In Fig. 2 is shown the total twist for the two sizes of specimens and for the rates of strain and temperatures used. There is a decrease in strain with increase in strain rate at room temperature and -100 F. whereas at 700 F. the strain increases with increase in strain rate from 0.5 to 27 rpm. Results of ductility of unnotched specimens of RC70 and RC130B do not indicate strain rate sensitivity

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* The numbers in parentheses refer to the references listed in the Bibliography.

for the rates of strain used. However, the specific strain rate for a notched specimen is higher for a given velocity of the loading head than for an unnotched specimen, and this may account for the decreased ductility found for A-110 tested at 1300 rpm. There is little difference in ductility at room temperature and -100 F. The ductility increases appreciably at 700 F. In data reported (3) by the manufacturer, the ductility of commercially pure titanium and some alloys as measured by elongation in static tension tests is not greatly affected by temperatures up to around 800 F. although the reduction of area has been reported to show marked increase above about 700 F.

The influence of strain rate and temperature on total energy absorbed as shown in Fig. 3 follows about the same pattern as does the total strain. The results for total energy as well as for total strain differ from those previously reported (2) for RC70 and RC130B in that for titanium A-110 there is a greater strain rate sensitivity and an increase in ductility and energy with increase in temperature up to 700 F.

Typical torque-twist curves for notched specimens of titanium are shown in Fig. 4. The influence of temperature and rate of strain on the shape of these curves is about the same as that for S. T. S. given in the April 1955 report (1). The major difference lies in the fact that at room temperature and low temperature, fracture instability occurs at a relatively higher torque for the titanium than for the S. T. S. previously reported. It may be observed from Fig. 4 that at these two temperatures the torque drops rather sharply from ultimate torque to zero torque. At 700 F, however, there is a more gradual drop-off in torque as was also the case for the S. T. S.

In Fig. 5 is shown the influence of speed on size effect as determined from post-crack energy and from total energy. The definition of size effect as used here is the same as that in the April 1955 report and is obtained from the equation:

$$\text{SIZE EFFECT} = m = 3 - \frac{\log W_2/W_1}{\log D_2 / D_1}$$

The curves show that, in general, size effect decreases with an increase in speed. The size effect as measured by post-crack energy is quite large at the low speed and at room temperature and low temperature. The size effect previously reported for the S. T. S. increased with increase in speed.

Acknowledgements

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Bibliography

1. P. G. Jones and T. J. Dolan, "Torsional Properties of Steels at High Rates of Strain." T. and A. M. Report No. 82. Department of Theoretical and Applied Mechanics, University of Illinois, April 1955.

2. C. E. Work and T. J. Dolan, "The Influence of Temperature and Rate of Strain on the Properties of Metals in Torsion." University of Illinois Eng. Exp. Station, Bulletin No. 420. (1953)

3. "Technical Information on Titanium Metal," Bulletin of Rem-Cru Titanium, Inc., Bridgeport, Connecticut.

TABLE I

SPEED	TEMPERATURE	SPECIMEN NUMBER	MODULUS OF RUPTURE	TOTAL TWIST	POST-CRACK ENERGY	TOTAL ENERGY		SPECIMEN NUMBER	MODULUS OF RUPTURE	TOTAL TWIST	POST-CRACK ENERGY	TOTAL ENERGY
RPM	°F		1000 psi	DEG.	in-lb.	in-lb.			1000 psi	DEG.	in-lb.	in-lb.
		D =	3/16	in.	r =	0.03	in.	D =	3/8	in.	r = 0.06 in	
0.5	-100	T-17	149.6	19.8	7.2	60.6		T-39	148.7	13.7	11.2	293
		T-18	142.2	16.5	3.4	43.9		T-40	152.6	13.5	14.0	300
		T-19	147.0	17.3	5.6	44.8		T-41	150.0	19.2	11.2	416
		Avg.	146.3	17.9	5.4	49.8		Avg.	150.4	15.5	12.1	336
	80	T-10	135.0	28.5	22.2	53.5		T-32	128.1	11.1	12.0	216
		T-11	135.6	19.1	9.8	42.0		T-33	131.9	12.0	16.0	239
		T-12	134.2	21.1	14.0	46.1		T-34	131.0	12.3	10.0	244
		Avg.	134.9	22.9	15.9	47.2		Avg.	130.3	11.8	12.7	233
	700	T-1	77.1	39.2	16.4	47.3		T-23	79.1	22.0	57.5	229
		T-2	79.5	47.9	19.1	45.9		T-24	77.9	22.6	78.7	206
		T-3	83.9	38.2	15.9	47.8		T-25	76.0	20.2	56.6	188
		Avg.	80.2	41.8	17.1	47.0		Avg.	77.7	21.6	64.3	208
27	-100	T-20	152.6	23.4	3.1	65.3		T-42	143.2	12.8	30.7	258
		T-21	154.6	20.2	5.6	55.5		T-43	148.6	12.4	28.6	261
		T-22	158.6	21.9	7.5	58.4		T-44	147.1	16.9	23.7	350
		Avg.	155.3	21.8	5.4	59.7		Avg.	146.3	14.0	27.7	290
	80	T-7	136.0	17.4	13.9	42.9		T-29	129.1	12.3	67.0	241
		T-8	131.8	22.5	7.5	49.0		T-30	128.4	12.5	89.0	255
		T-9	137.9	24.9	22.7	53.7		T-31	133.9	12.2	58.0	248
		Avg.	135.2	21.6	14.7	48.5		Avg.	130.5	12.3	71.3	248
	700	T-4	84.8	51.9	25.2	54.6		T-26	80.0	26.4	112.0	242
		T-5	83.8	62.3	30.7	65.1		T-27	81.7	21.3	63.0	223
		T-6	84.7	47.7	26.2	55.4		T-28	81.4	40.5	140.0	318
		Avg.	84.4	54.0	27.4	58.4		Avg.	81.0	29.4	105.0	261
1300	-100	T-15	157.3	12.6	10.4	25.6		T-37	150.1	8.6	52.3	152
		T-16	156.0	12.6	7.4	24.5		T-38	125.2	8.7	48.8	154
		Avg.	156.6	12.6	8.9	25.0		Avg.	137.6	8.6	50.6	153
	80	T-13	143.8	10.8	9.3	29.7		T-35	NO	GOOD		
		T-14	141.5	8.2	4.4	22.0		T-36	135.8	11.0	34.2	211
		Avg.	142.6	9.5	6.8	25.8		Avg.	135.8	11.0	34.2	211

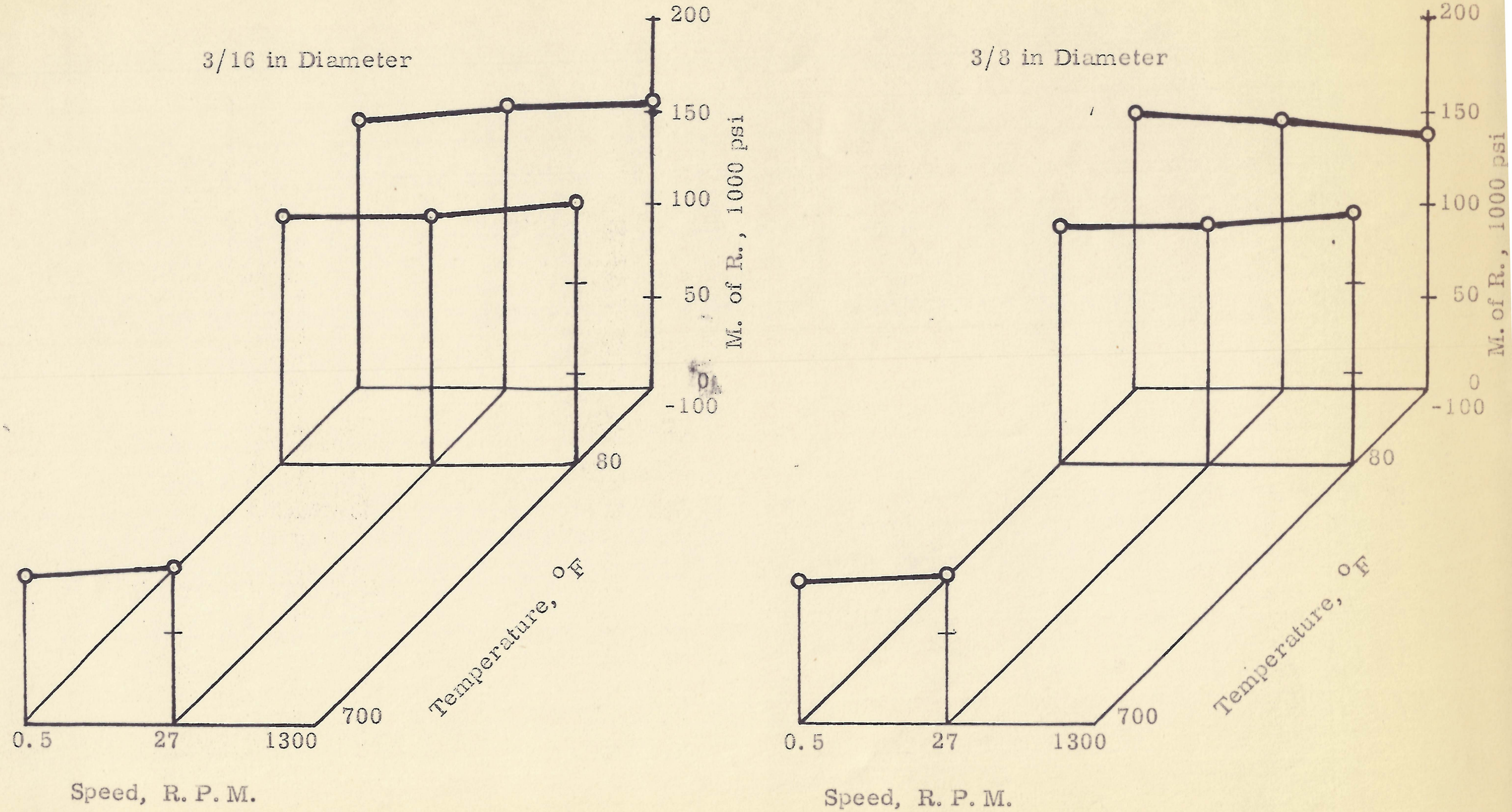
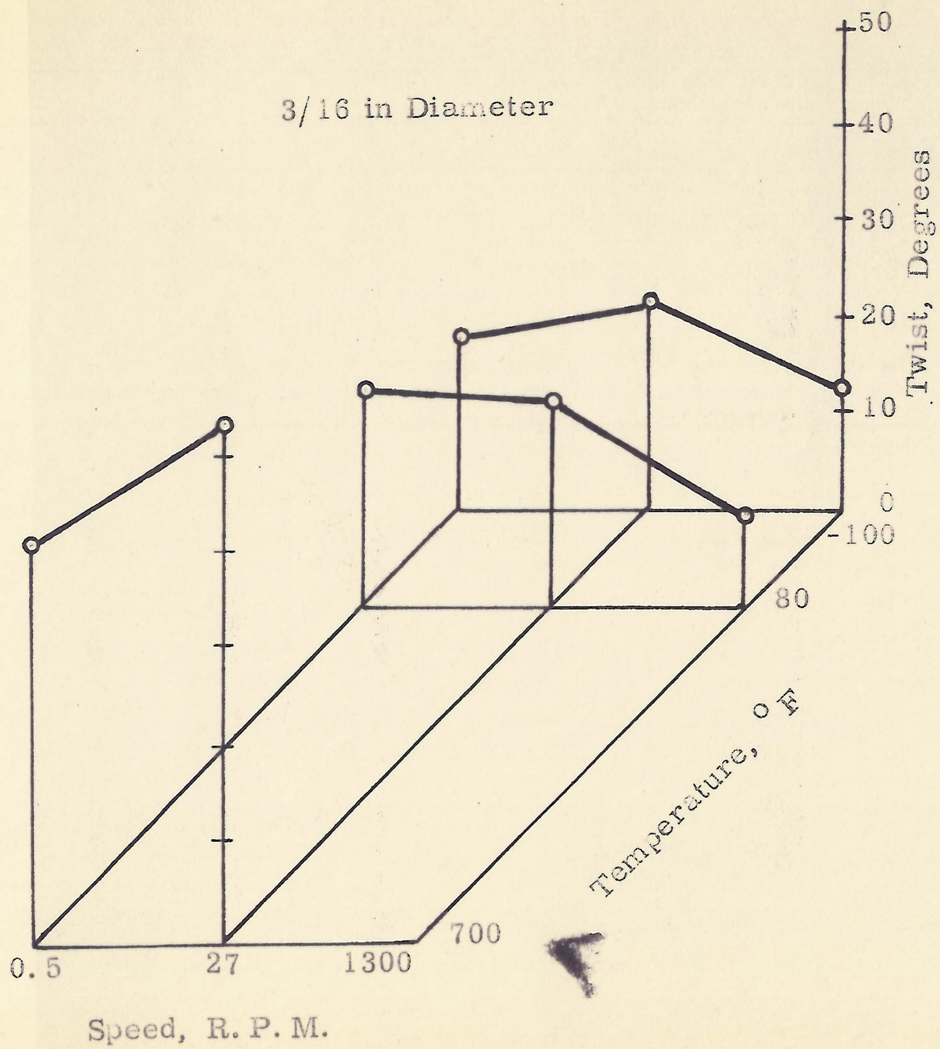


Fig. 1 Modulus of Rupture for Titanium ($\frac{r}{D}$ = 0.160)



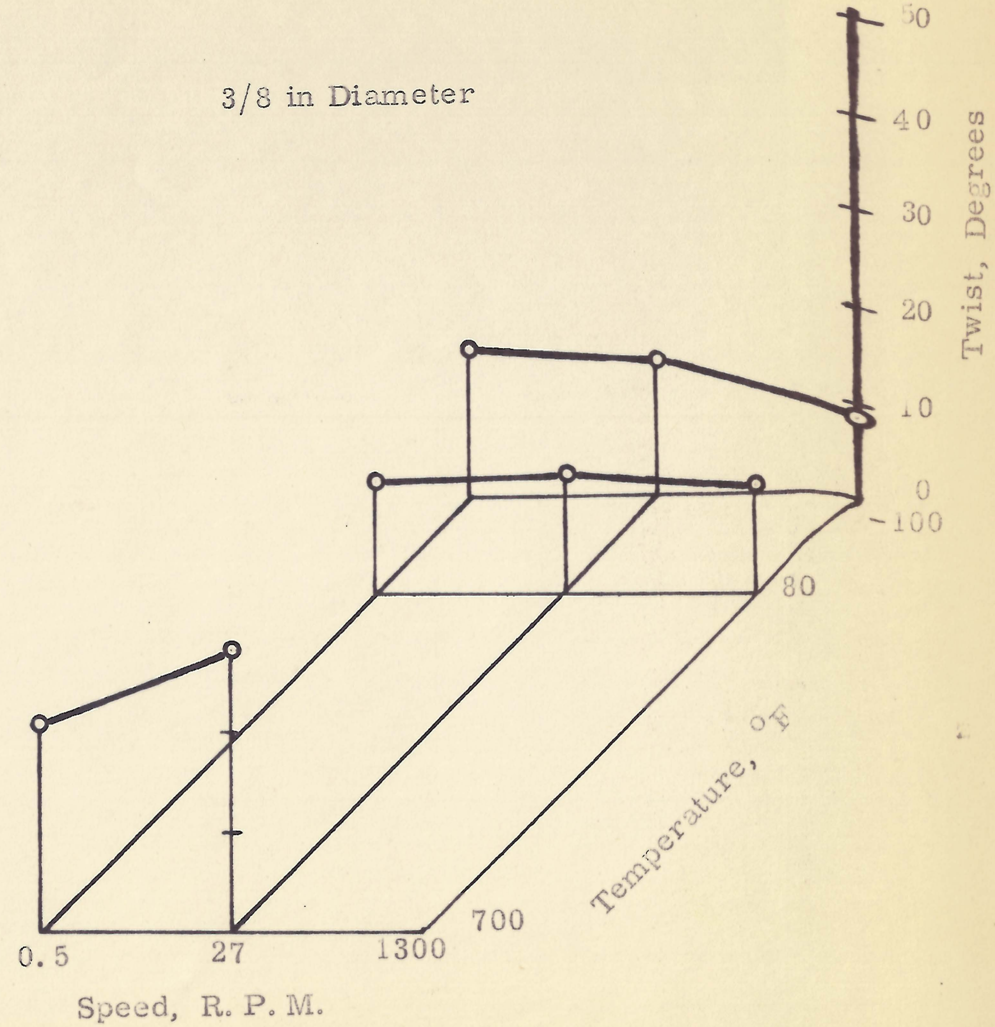


Fig. 2 Total Twist for Titanium ($\frac{t}{D}$ = 0.160)

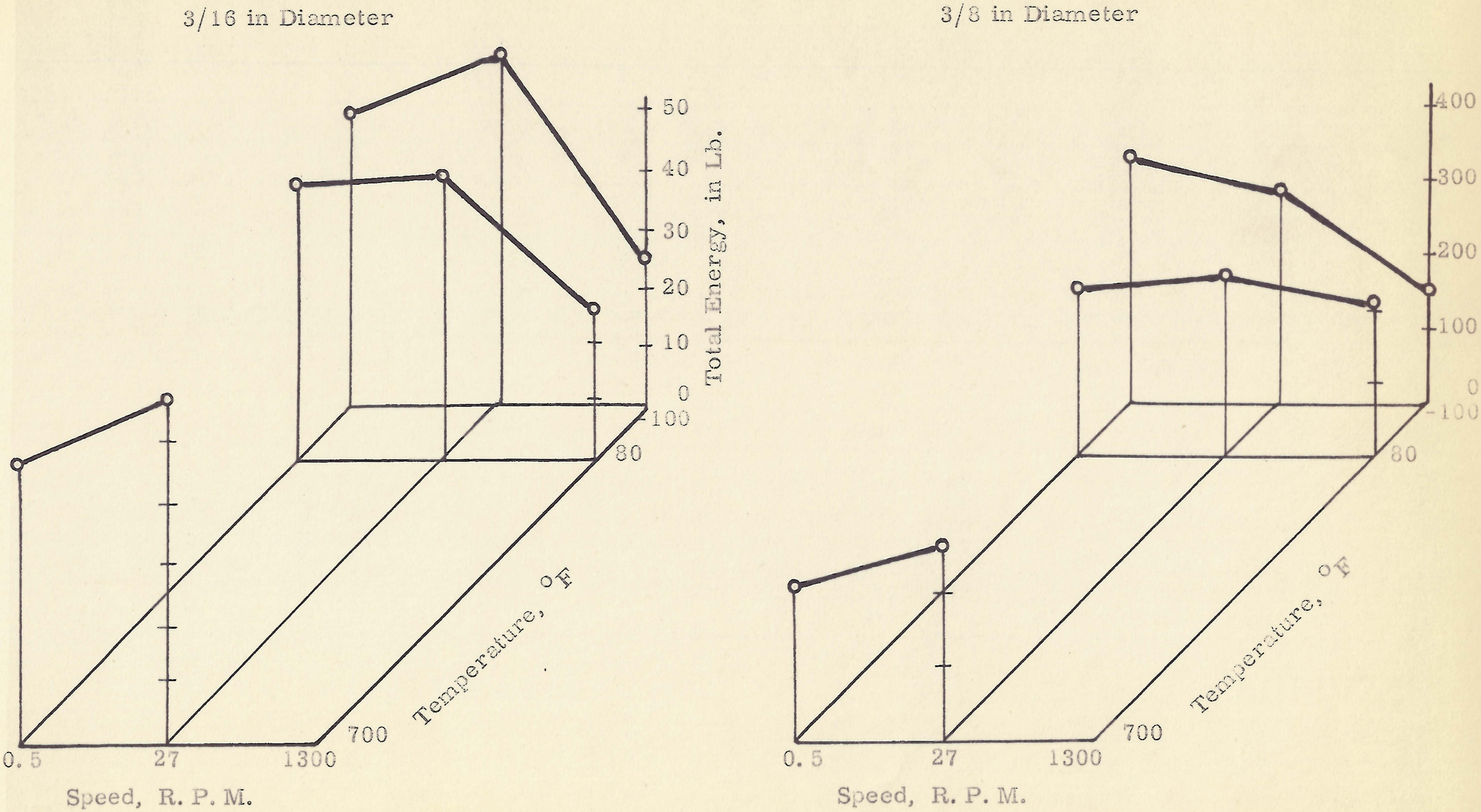


Fig. 3 Total Energy Absorbed for Titanium ($\frac{r}{D}$ = 0.160)

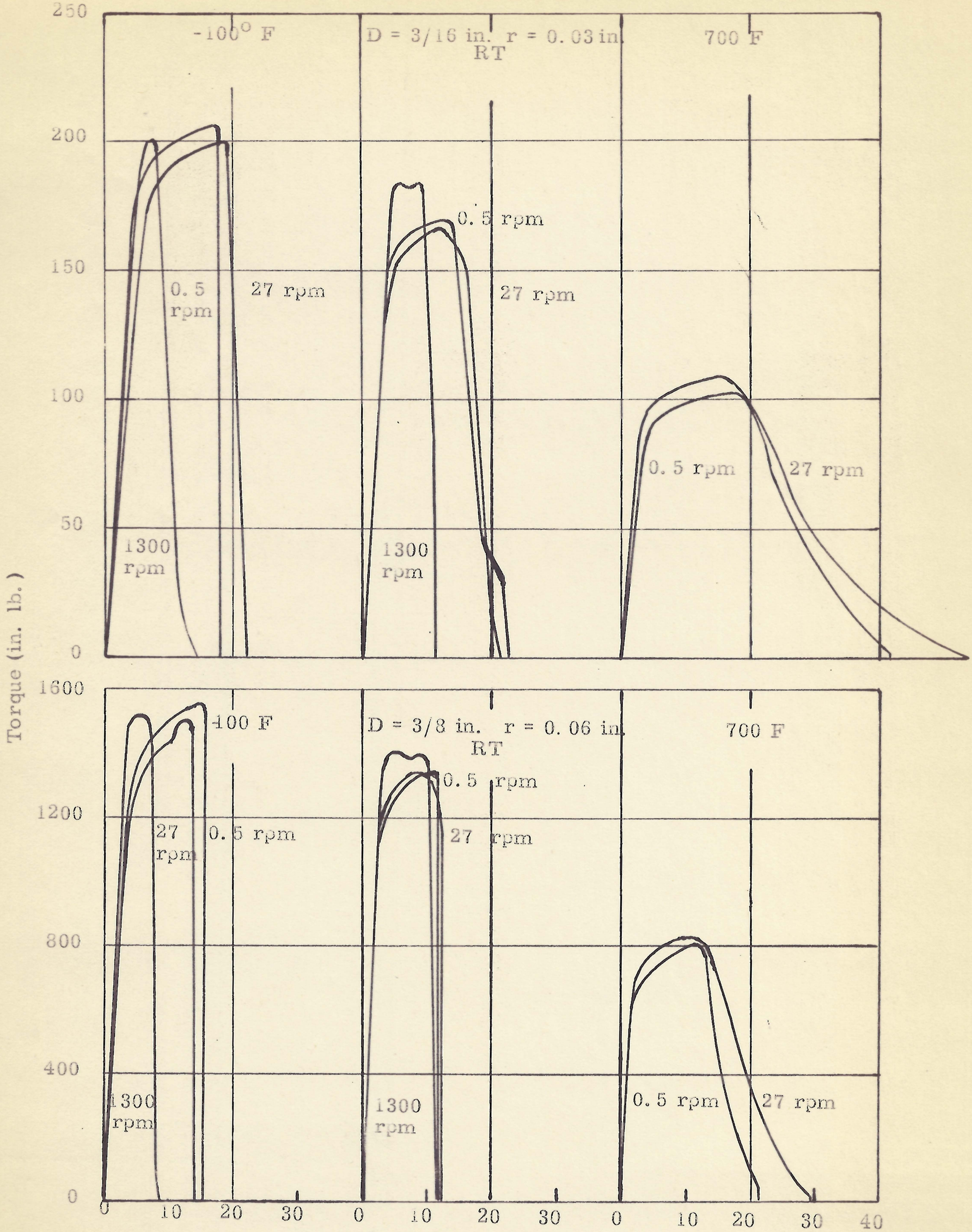


Fig. 4 Typical Torque Twist Curves for Notched Specimens of Titanium

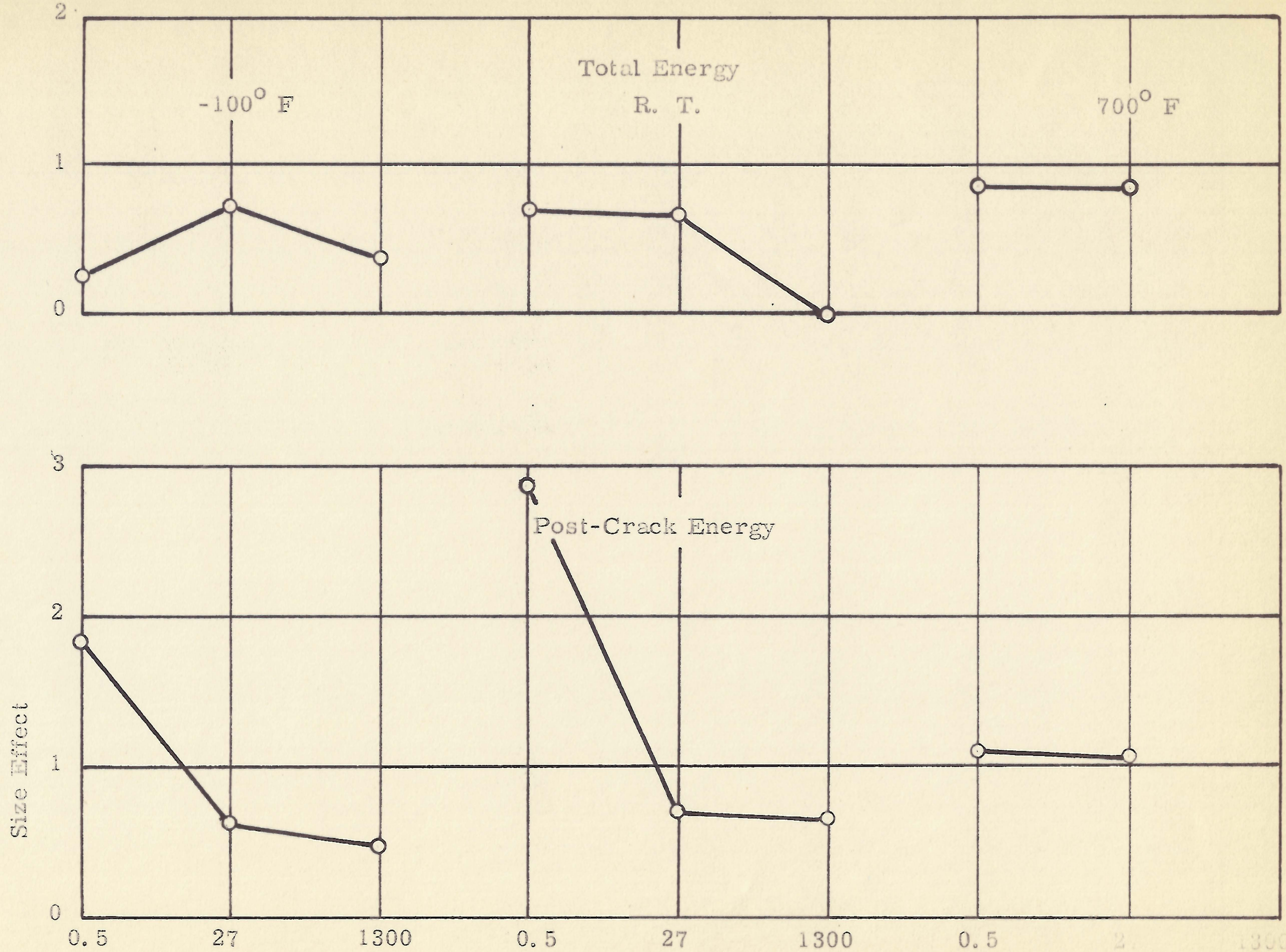


Fig. 5 Influence of Speed on Size Effect ($\frac{r}{D}$ = 0. 160)